

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
19 August 2004 (19.08.2004)

PCT

(10) International Publication Number
WO 2004/070323 A1

(51) International Patent Classification⁷: **G01F 1/58**, 1/60

(21) International Application Number:

PCT/SE2004/000097

(22) International Filing Date: 26 January 2004 (26.01.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

0300342-3 10 February 2003 (10.02.2003) SE
60/523,723 19 November 2003 (19.11.2003) US

(71) Applicant (for all designated States except US): **GAMBRO LUNDIA AB** [SE/SE]; Magistratsvägen 16, P.O. Box 10101, S-220 10 Lund (SE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **HALLSTADIUS, Hans** [SE/SE]; Vapenkroken 28, S-226 47 Lund (SE). **OHLSSON, Göran** [SE/SE]; Box 9, S-286 21 Örkelljunga (SE). **GUSTAFSON, Sven** [SE/SE]; Sangarevägen 14 F, S-224 71 Lund (SE). **JONASSON, Bengt** [SE/SE]; Kommunistergatan 1, S-242 32 Hörby (SE). **BERTINSSON, Gert-Inge** [SE/SE]; Nyckelkroken, S-226 47 Lund (SE).

(74) Agents: **BJERKÉNS PATENTBYRÅ KB** et al.; Östermalmsgatan 58, S-114 50 Stockholm (SE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

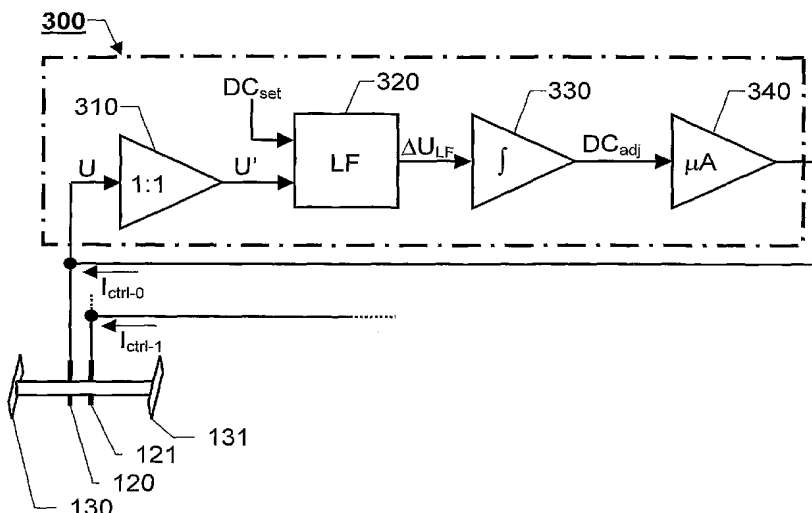
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

[Continued on next page]

(54) Title: A FLOW SENSOR AND METHOD FOR MEASURING A FLOW RATE COMPONENT OF A FLUID CONTAINING ELECTRICALLY CHARGED ELEMENTS



(57) Abstract: The invention relates to measurement of a fluid flow, wherein a flow rate component of the fluid is measured along a selected direction. A magnetic field whose polarity varies over time is applied to the fluid, which presumed to contain electrically charged elements. First and second sensor electrodes (120, 121) are arranged to be wetted by the flowing fluid. The electrodes (120, 121) are spaced apart from one another along a line being substantially perpendicular both to the selected flow direction and a magnetic axis of the magnetic field. A DC-level drift of the sensor electrodes (120, 121) is prevented by supplying a control current (I_{ctrl-0} ; I_{ctrl-1}) to each of the sensor electrode (120, 121), which has such sign and magnitude that a direct-current voltage level at the sensor electrodes (120, 121) relative a reference potential is controlled towards a predetermined voltage (DC_{set}).

WO 2004/070323 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A flow sensor and method for measuring a flow rate component
of a fluid containing electrically charged elements

5 THE BACKGROUND OF THE INVENTION AND PRIOR ART

The present invention relates generally to measurement of a fluid flow. More particularly the invention relates to a flow sensor according to the preamble of claim 1, an ultra-filtration measuring unit according to the preamble of claim 8 and a method
10 for measuring a flow rate component according to the preamble of claim 10.

There are many technical areas in which an accurate fluid flow measurement is required. Numerous representative applications can, for instance be found in the field of medical technology.
15 However, some kind of flow measurement is normally required in most instances where a fluid/liquid is to be transported from one point to another. Fluid flow measurements may also be used to determine the velocity of a craft traveling in water or a similar liquid. Naturally, mechanical flow sensors may here be employed. Nevertheless, when a high accuracy is required, electro-
20 magnetic flow measurement sensors are generally preferable. This type of sensors are based on a well-known technique where a magnetic field is applied to interact with electrically charged elements, such as ions, in the flowing fluid to produce a
25 resulting electric field. Thus, according to Faraday's law, the magnitude of the induced electric field constitutes a measure of the flow rate of the fluid.

The applicant develops and manufactures medical equipment, for instance renal products in the form of dialysis apparatuses,

which utilize such an electromagnetic flow measurement technique. Commonly, flow sensors with platinum electrodes have been employed to deliver accurate and reliable values of the registered fluid flows. Platinum, and platinum black in particular, namely accomplishes a good electrical contact between the electrodes and the dialysis liquid, so that the electrode dimensions can be held comparatively small, and consequently give rise to a linear magnetic field pattern in the fluid conduit cross section.

10 In recent years, a so-called glucose-charging practice has been introduced wherein glucose is added to the dialysis liquid in order to better imitate the composition of the patient's own blood, and thereby i.a. avoid certain metabolic risks for the patient. However, glucose also produces undesired effects due to its electrochemical activity with platinum. During operation of a dialysis apparatus with a glucose-charged dialysis liquid, a catalytic reaction causes glucose to be oxidized on the flow sensors' platinum surfaces. This decreases the reliability of the flow measurements. Namely, the oxidation may result in a varying DC-level (DC = Direct Current) at the sensor electrodes, which in turn renders it difficult to determine the contribution to the registered electric field caused by the electromagnetic interaction between the applied magnetic field and the charged elements in the flowing liquid (i.e. here ions in the dialysis liquid).

The U.S. Patent Application No. 2002/0050175 describes a magnetic flow sensor and method, wherein an undesired drift of the electrode voltages is compensated for, either by interconnecting the sensing electrodes or by connecting them to a common potential, such as ground. Also in this case, a voltage indicative of the flow rate is measured by means of at least two electrodes. A high-impedance voltage-measurement circuit is used to register a voltage between the electrodes. Thus, during the measurement, the electrodes are in an open circuit state, and may therefore be electrically influenced by electrode polarization

and other measurement error-inducing factors that develop relatively slowly. In order to avoid such effects, the electrodes are in a closed circuit state for most of the time and placed in an open circuit state only during a relatively brief measurement interval portion of the operating cycle.

Although this strategy may solve the drifting problem, it results in a limited maximum sampling frequency, and consequently also an accuracy constraint with respect to the detection of rapid changes in the flow rate. Moreover, the procedure requires a considerable amount of high-speed switching, and is therefore both expensive to implement and relatively prone to malfunction.

SUMMARY OF THE INVENTION

The object of the present invention is therefore to alleviate the problems above and thus accomplish a flow measurement solution through which an accurate fluid flow rate can be determined also when the sensor electrodes may be electrochemically affected by the fluid and its constituents.

According to one aspect of the invention, the object is achieved by the initially described flow sensor, which is characterized in that it comprises at least one direct current supply circuit adapted to feed a respective control current to each of the first and second sensor electrodes in the electric sensor arrangement. Each control current has such sign and magnitude that a DC-voltage level at the first and second sensor electrodes relative to a reference potential is controlled towards a predetermined voltage.

An important advantage attained by this strategy is that any DC-level drift which otherwise could have occurred due to an oxidation of one or more of the sensor electrodes is prevented. At the same time, the flow measurement may be performed continuously, and/or flow rate sample values may be generated at an arbitrary frequency.

According to a preferred embodiment of this aspect of the invention, the at least one direct current supply circuit includes a differential low-pass filtering unit, an integrator unit and a controllable current generator. The differential low-pass filtering unit is adapted to generate a low-pass filtered difference signal representing a variance between the predetermined voltage and the registered voltage. The integrator unit is adapted to receive the low-pass filtered difference signal, and in response thereto, produce an adjustment signal. Finally, the controllable current generator is adapted to produce the control current in response to the adjustment signal. This design of the current supply circuit is advantageous because it accomplishes a reliable delivery of the control current with relatively simple means.

According to yet a preferred embodiment of this aspect of the invention, the at least one direct current supply circuit includes a high-input impedance buffer unit, which is adapted to receive a primary voltage signal from the electric sensor arrangement. In response thereto, the buffer unit generates a buffered voltage signal which reflects the voltage at the sensor electrodes. Naturally, an important function of the buffer unit is to prevent the control current from being fed back via the direct current supply circuit.

According to another preferred embodiment of this aspect of the invention, the conduit section includes at least one reference electrode in addition to the first and second sensor electrodes. This at least one reference electrode is adapted to produce a reference potential in the flowing fluid to which the voltage that is registered at the sensor electrodes is related. Either the at least one reference electrode applies a particular voltage, such as a ground voltage to the flowing fluid, or instead, the at least one reference electrode is used to register an externally applied voltage. In any case, the at least one reference electrode alleviates an accurate registration also of very small voltages between the sensor electrodes, which of course, is desirable feature.

According to still another preferred embodiment of this aspect of the invention, a fluid contact surface of at least one of the sensor electrodes contains platinum, for instance by being at least partly covered with platinum black. An important advantage is namely attained with this material, since it has an extremely large surface area. Thus, good electrical contact between the electrode and the fluid may be obtained via an electrode that has comparatively small dimensions.

According to another aspect of the invention, the object is achieved by the initially described ultra-filtration measuring unit, which is characterized in that it contains at least one flow sensor of the above-proposed type. Such an ultra-filtration measuring unit, for instance, enables reliable flow measurements in a dialysis apparatus where the dialysis liquid contains glucose. This is a highly desired characteristic in today's renal medicine.

According to a preferred embodiment of this aspect of the invention, the ultra-filtration measuring unit includes a measurement cell, wherein a first flow sensor is arranged with its conduit section in parallel with the conduit section of a second flow sensor, such that a common magnetic field may magnetize flowing fluid in both sensors. This design is advantageous because thereby, the circuitry for accomplishing the magnetization can be made relatively uncomplicated.

According to another aspect of the invention, the object is achieved by the initially described method for measuring a flow rate component, which is characterized by feeding at least one control current to an electric sensor arrangement for registering the voltage. The control current here has such sign and magnitude that a direct-current voltage level at the electric sensor arrangement is controlled towards a predetermined voltage, for example zero volt in relation to a reference potential.

As mentioned above, any DC-level drift which otherwise could have occurred due to an oxidation of one or more of the sensor

electrodes is thereby prevented. At the same time, the flow measurement may be performed continuously, and/or flow rate sample values may be generated at an arbitrary interval. Both of these attributes are both highly desirable, particularly in medical applications.

According to a preferred embodiment of this aspect of the invention, the method includes the following steps. First, the registered voltage is compared with the predetermined voltage to produce a variance between the voltages. Then, a direct-current voltage component is extracted from this variance, which forms a basis for a control current. Finally, the control current is fed to the electric sensor arrangement, such that the direct-current voltage level at the electric sensor arrangement is controlled towards the predetermined voltage. It is generally preferable to complete these steps continuously and in parallel, such that for instance, during extraction of the DC-voltage from a particular variance, the variance between a somewhat later registered voltage and the predetermined voltage is determined, and so on.

According to yet a preferred embodiment of this aspect of the invention, the production of the control current involves the following sub-steps. First, an adjustment signal is received, which reflects the direct-current voltage component of the variance between the registered voltage and the predetermined voltage. Then, based on the adjustment signal, the control current is generated. Hence, an adaptive and straightforward regulation of the control current is accomplished.

According to another preferred embodiment of this aspect of the invention, the magnetic field has a base frequency which is different from a multiple of a typical electricity supply network frequency, such as 50 or 60 Hertz. Thereby, undesired resonance phenomena may namely be avoided.

Although the invention enhances the accuracy and reliability of flow measurements performed with respect to a fluid that risks

interacting electrochemically with the sensor electrodes, the proposed solution is equally well suited for flow measurements of any non-corrosive fluids. The only requirement is that the fluid contains at least some amount of electrically charged elements.

5 BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is now to be explained more closely by means of preferred embodiments, which are disclosed as examples, and with reference to the attached drawings.

- 10 Figure 1 shows a schematic view of a flow sensor according to the invention,
- Figure 2a shows a graph illustrating a magnetizing current which controls a magnetic field across a conduit section of the flow sensor according to an embodiment of the invention,
- 15 Figure 2b shows a graph illustrating a corresponding electric field induced in the flowing fluid as a result of the magnetic field being produced by the magnetizing current illustrated in figure 2a,
- 20 Figure 3 depicts a block diagram over a proposed direct current supply circuit which feeds such a current to the sensor electrodes that their DC-voltage level is controlled towards a predetermined voltage,
- Figure 4 shows a flow diagram which illustrates the general method according to the invention, and
- 25 Figure 5 shows a schematic view of an ultra-filtration measuring unit according to an embodiment of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

A schematic view of a flow sensor according to the invention is shown in figure 1. The sensor includes a conduit section 100 for receiving a fluid flow, a magnet driver 115 for controlling the polarity and intensity of a magnetic field B across the conduit section 100, and a voltage sensor 125 for registering a voltage U induced in the fluid flow by means of the magnetic field B .

The sensor measures a flow rate component Q along a selected direction of a fluid that flows through the conduit section 100. The selected direction (indicated with bold arrows) here coincides with longitudinal extension of the conduit section 100. The flow rate component Q is measured over the conduit section's 100 cross-section area D which, for illustrating purposes, in this example has a rectangular shape with a width w and a height h . In practice, however, any alternative cross-section shape is conceivable.

The fluid is presumed to contain electrically charged elements, such as ions. These elements are transported by the flowing fluid through the conduit section 100 at an average velocity v in the selected direction. A pair of controllable magnetizing means 110 and 111 respectively are arranged substantially opposite to each other in the conduit section 100, for example on the side walls. The magnetizing means 110 and 111 are oriented such that a magnetic axis between them is substantially perpendicular to the selected flow direction. Moreover, each magnetizing means 110 and 111 contains a conductor coil, which is electrically connected to the magnet driver 115. Thereby, by means of a magnetizing current I_B , the magnet driver 115 may generate a magnetic field B across the conduit section 100 between the magnetizing means 110; 111 whose intensity depends on the magnitude of the magnetizing current I_B , which is sent through the conductor coils. The polarity of this magnetic field B is determined by the sign (i.e. direction) of the magnetizing current I_B .

Figure 2a shows an exemplary graph for such a magnetizing current I_B for controlling the magnetic field B . Preferably, the current direction in the conductor coils of the magnetizing means 110 and 111 is reversed after each period of the magnetizing current I_B (e.g. in connection with the negative edge from I_B^+ to I_B^-) by means of a switching operation, such that at the same time, the polarity of the magnetic field is altered. Due to the linear relationship between the magnetizing current I_B and the magnetic field B , the graph in figure 2a could, in fact, also be regarded as an illustration of the intensity of the magnetic field B as a function of time t . However, it should be borne in mind that the current direction is reversed after completion of each magnetizing current period. Thus, one period of the magnetic field corresponds to two magnetizing current periods.

According to Faraday's law, an electric field E is produced in the flowing fluid as a result of an interaction between the electrically charged elements in the fluid and the magnetic field B . The electric field E has its maximum component in a direction, which is perpendicular to both the direction of the (largest) flow component and the axis of the magnetic field B , and may be expressed as $E = v \times B$, where v represents the average velocity and B represents the magnetic field.

An electric sensor arrangement is used to register the electric field E by means of a first sensor electrode 120 and a second sensor electrode 121. The sensor electrodes 120 and 121 are arranged in the conduit section 100 to be wetted by the flowing fluid therein. According to a preferred embodiment of the invention, the fluid contact surface of the sensor electrodes 120 and 121 contains platinum, and more preferably, is at least partly covered with platinum black. Furthermore, in order to enable registration of a largest possible electrical field vector, the sensor electrodes 120 and 121 are spaced apart from one another along a line which is substantially perpendicular both to the selected flow direction and the magnetic axis of the magnetic field B . The voltage sensor 125 is electrically con-

nected both to the first sensor electrode 120 and the second sensor electrode 121, so that the voltage sensor 125 may register a voltage U between the electrodes 120 and 121.

Thus, in this example, where the sensor electrodes 120 and 121
5 are arranged on the floor and top walls of the conduit section 100, the distance between the sensor electrodes 120 and 121 is equal to the height h of the conduit section 100. Therefore, a voltage component V_Q between the sensor electrodes 120 and 121 caused by the interaction between the electrically charged
10 elements in the fluid and the magnetic field B may be expressed as: $V_Q = v \cdot B$. The relationship between the flow rate component Q and the average velocity v is: $Q = v \cdot D \cdot B$, where D denotes the cross-section area of the conduit section 100. Consequently, the voltage component V_Q may be expressed as $V_Q = Q/D$. The fact
15 that the area D is constant renders the voltage component V_Q proportional to the flow rate component Q . Moreover, it is generally preferable to measure the voltage U between the sensor electrodes 120 and 121 at time instances when the magnetic field has a particular (and substantially constant) value. Figure
20 2b shows an exemplary graph which illustrates how a voltage component V_Q may be defined based on measurements of the voltage U between the sensor electrodes 120 and 121.

According to a preferred embodiment of the invention, the conduit section 100 includes at least one reference electrode in
25 addition to the first and second sensor electrodes 120 and 121. The flow sensor in figure 1 has two such reference electrodes 130 and 131, which both are adapted to produce a reference potential for the voltage U . Technically however, one reference electrode is sufficient. Typically, the reference voltage represents a ground potential applied to the flowing fluid in the
30 conduit section 100 by means of the reference electrodes 130 and 131. However, any other electric potential is conceivable. According to an alternative embodiment of the invention, instead of applying a voltage, the reference electrodes 130 and 131
35 register an externally applied voltage to the fluid.

Since, preferably, the polarity of the magnetic field B varies regularly, for example in response to a magnetizing current I_B according to the graph in figure 2a and a switching operation performed at the end of each period, the DC-component of the registered voltage U lacks interest for the flow measurement. Therefore, the DC-component should be suppressed. The reference electrodes 130 and 131 facilitate this suppression by supplying to the voltage sensor 125 an appropriate value of the DC-voltage level that is present in the flowing fluid, so that this component may be subtracted from the registered voltage U .

Figure 2b shows a graph that illustrates an exemplary voltage U registered between the sensor electrodes 120 and 121 when the magnetizing current I_B illustrated in figure 2a is fed to the magnetizing means 110 and 111, and a switching operation which alters the current direction is performed after completion of each period. In the illustrated example, the voltage signal U contains a DC-component U_{DC} , and as a result of said switching operation, two magnetizing current I_B periods corresponds to one induced voltage U period.

In order to avoid the occurrence of undesired resonance phenomena, it is preferable to select the base frequency of the magnetic field B to a value being different from a multiple of a typical electrical supply network frequency (such as 50 Hz or 60 Hz). Consequently, 401 Hz constitutes one example of a suitable magnetic field frequency.

Preferably, the voltage signal U is sampled at time instances t_1 and t_2 , when the signal has attained a stable value (e.g. corresponding to when the magnetizing current I_B has reached a constant positive level I_B^+ , shortly prior to switching over to a negative current value I_B^-). Due to the varying polarity of the magnetic field B , the voltage signal U also varies over time. A first relatively stable voltage level V_Q^+ and a second relatively stable voltage level V_Q^- respectively (corresponding to the constant level I_B^+ of the magnetizing current I_B) may be registered

at the sampling instances t_1 , t_2 and so on. The voltage difference V_Q between the voltage levels V_Q^+ and V_Q^- here constitutes a measure of the flow rate Q of the fluid flowing through the conduit section 100.

5 According to the invention, the flow sensor also includes at least one direct current supply circuit 300, which is adapted to feed a control current I_{ctrl-0} to the electric sensor arrangement (i.e. each of the first and the second sensor electrodes 120 and 121) of such sign and magnitude that the DC voltage level at the sensor
10 electrodes 120 and 121 relative a reference potential (e.g. produced by the reference electrodes 130 and 131) is controlled towards a predetermined voltage, say zero volts. Figure 3 depicts a block diagram over a proposed direct current supply circuit for supplying a control current I_{ctrl-0} to the first sensor
15 electrode 120. An equivalent direct current supply circuit is also used to produce a corresponding control current I_{ctrl-1} to the second sensor electrode 121, however for reasons of simplicity, this circuit is not explicitly depicted in the figure.

The direct current supply circuit 300 includes a differential low-pass filtering unit 320, an integrator unit 330 and a controllable
20 current generator 340. Preferably, the direct current supply circuit 300 also includes a high-input impedance buffer unit 310, which is adapted to receive a primary voltage signal U from the electric sensor arrangement, and in response thereto, generate
25 a buffered voltage signal U' reflecting the voltage at the first sensor electrode 120 and the second sensor electrode 121. The differential low-pass filtering unit 320 receives the registered voltage U (either directly from the electric sensor arrangement, or via the buffer unit 310), receives a predetermined voltage
30 DC_{set} (typically generated on basis of values at the reference electrodes 130 and 131), and extracts there from a low-pass filtered difference signal ΔU_{LF} representing a DC-difference value between the predetermined voltage DC_{set} and the registered voltage signal U (or U'). The integrator unit 330 is
35 adapted to receive the low-pass filtered difference signal ΔU_{LF} ,

and in response thereto, produce an adjustment signal DC_{adj} , which represents a measure of how much the DC-voltage level at the electric sensor arrangement should be adjusted in order to reach the desired voltage DC_{set} . Thus, the differential low-pass filtering unit 320 and the integrator unit 330 together form the PI-part of a PI-regulator for the DC-voltage at the electric sensor arrangement.

The controllable current generator 340 is adapted to receive the adjustment signal DC_{adj} , and in response thereto, produce the control current I_{ctrl-0} , which is fed to the first sensor electrode 120 in the electric sensor arrangement. Analogous thereto, a corresponding control current I_{ctrl-1} is fed to the second sensor electrode 121. Thereby, the DC-voltage level at the sensor electrodes 120 and 121 is controlled towards the predetermined voltage.

Figure 4 shows a flow diagram illustrating the general method according to the invention for measuring a flow rate component of a fluid, which contains electrically charged elements.

The method presupposes that the fluid is magnetized by means of a magnetic field B having a periodically alternating polarity and a magnetic axis which is oriented substantially perpendicular to a selected flow direction along which the flow rate is to be measured. Moreover, a voltage is registered across the flowing fluid along a line being substantially perpendicular both to the selected flow direction and the magnetic axis.

A first step of the method 410, registers a sensor electrode voltage. Then, a step 420 extracts a DC-voltage component from the registered voltage and compares the DC-voltage component with a predetermined voltage that represents a reference value with respect to the DC-voltage level of the flow sensor. Subsequently, a step 430 generates an adjustment signal, which in turn forms a basis for producing a control current. After that, a step 440 feeds this control current to the sensor electrodes. The

control current has such sign and magnitude that the direct-current voltage level at the sensor electrodes is controlled towards the predetermined voltage.

5 Figure 5 shows a schematic view of an ultra-filtration measuring unit 500 according to an embodiment of the invention. The unit 500 may be used to regulate the flows of dialysis liquid (e.g. containing glucose) to and from a dialysis apparatus.

10 The proposed ultra-filtration measuring unit 500 includes a pump 530, a measurement cell 510, and valves 540, 550, 555 and 560. The pump 530 assists in accomplishing a desired flow Q' of uncontaminated dialysis liquid to the dialysis apparatus D_{in} . The valves 540, 550, 555 and 560 are used to control the ultra-filtration volume per time unit. An output flow D_{out} of used dialysis liquid from the dialysis apparatus is received by the unit
15 500 via the valve 550, and fed out for discarding Q'' via the measurement cell 510.

20 The measurement cell 510 contains a first flow sensor 100a located in a first flow channel and a second flow sensor 100b located in a second flow channel. The flow sensors 100a and 100b are arranged with their conduit sections in parallel with each other, such that a common magnetic field may magnetize flowing fluid in both the first flow sensor 100a and the second flow sensor 100b. This design is namely advantageous because thereby, the circuitry for accomplishing the magnetization can be
25 made relatively uncomplicated. The measurement cell 510 measures the flow rate of dialysis liquid into the dialysis apparatus D_{in} via the first flow channel, and a corresponding flow rate D_{out} from the dialysis apparatus via the second flow channel. Thus, by measurements performed in the measurement
30 cell 510, the flow rates D_{in} (Q') and D_{out} (Q'') can be controlled to obtain a desired ultra-filtration volume per time unit.

In order to prevent (or at least minimize) calculation errors in the flow measurements, the measuring unit 500 performs self-

calibration, by means of a so-called taration procedure, at regular intervals (typically once every 30 minutes during the dialysis treatment).

5 The taration procedure includes one phase in which a zero-flow is measured. Here, the valve 540 is open and the valves 550, 555 and 560 are closed, so that the flow Q' of uncontaminated dialysis liquid is fed out directly for discarding Q'' without passing the measurement cell 510 or the dialysis apparatus.

10 In another phase of the taration procedure, a differential flow between the two flow channels is measured and set to zero. Here, the valve 555 is open while the valves 540, 550 and 560 are closed, so that the flow Q' of uncontaminated dialysis liquid passes the measurement cell 510 via both the first and the second flow channels, and is then fed out for discarding Q'' (i.e. 15 without passing the dialysis apparatus). Preferably, in this phase, the flow Q' is set to a standardized and well-defined value, say 500 ml/minute.

Based on the above zero-flow- and differential-flow-measure-
20 ments any adjustments necessary to the flow rate calculations performed on the values delivered by the measurement cell 510 can be made, so that systematic future calculation errors are avoided.

25 The term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components. However, the term does not preclude the presence or addition of one or more additional features, integers, steps or components or groups thereof.

30 The invention is not restricted to the described embodiments in the figures, but may be varied freely within the scope of the claims.

Claims

1. A flow sensor for measuring a flow rate component (Q) of a fluid, which contains electrically charged elements, along a selected direction, comprising:
- 5 a conduit section (100) for transporting the fluid;
first and second controllable magnetizing means (110, 111) arranged substantially opposite to each other in the conduit section (100), the first and second magnetizing means (110, 111) being oriented such that a magnetic axis between them is
- 10 substantially perpendicular to the selected flow direction of the fluid in the conduit section (100);
a magnet driver (115) adapted to control the polarity of a magnetic field (B) between the first and the second magnetizing means (110, 111);
- 15 an electric sensor arrangement including first and second sensor electrodes (120, 121) which are arranged in the conduit section (100) to be wetted by the flowing fluid therein, the first and second sensor electrodes (120, 121) being spaced apart from one another along a line being substantially perpendicular
- 20 both to the selected flow direction and the magnetic axis; and
a voltage sensor (125) adapted to register a voltage (U) between the first sensor electrode (120) and the second sensor electrode (121),
- 25 **characterized in that** the flow sensor comprises at least one direct current supply circuit (300) adapted to feed a respective control current (I_{ctrl-0} ; I_{ctrl-1}) to each of the first and second sensor electrodes (120, 121) in the electric sensor arrangement, the control currents (I_{ctrl-0} ; I_{ctrl-1}) each having such sign and magnitude that a direct-current voltage level at the first and
- 30 second sensor electrodes (120, 121) relative to a reference potential is controlled towards a predetermined voltage (DC_{set}).
2. A flow sensor according to claim 1, **characterized in that** each of the at least one direct current supply circuit (300) comprises:

- a differential low-pass filtering unit (320) adapted to generate a low-pass filtered difference signal (ΔU_{LF}) representing a variance between the predetermined voltage (DC_{set}) and the registered voltage (U);
- 5 an integrator unit (330) adapted to receive the low-pass filtered difference signal (ΔU_{LF}) and in response thereto produce an adjustment signal (DC_{adj}); and
- 10 a controllable current generator (340) adapted to produce the control current (I_{ctrl-0}) in response to the adjustment signal (DC_{adj}).
3. A flow sensor according to claim 2, **characterized in that** each of the at least one direct current supply circuit (300) comprises a buffer unit (310) adapted to receive a primary voltage signal (U) from the electric sensor arrangement and in
- 15 response thereto generate a buffered voltage signal (U') reflecting the voltage at the first sensor electrode (120) and the second sensor electrode (121), wherein an input of the buffer unit (310) for receiving the primary voltage signal has a relatively high impedance.
- 20 4. A flow sensor according to any one of the preceding claims, **characterized in that** the conduit section (100) comprises at least one reference electrode (130; 131) in addition to the first and second sensor electrodes (120, 121), the at least one reference electrode (130; 131) being adapted to produce a
- 25 reference potential for registering the voltage (U).
5. A flow sensor according to any one of the preceding claims, **characterized in that** the fluid contains glucose.
6. A flow sensor according to any one of the preceding claims, **characterized in that** a fluid contact surface of at least
- 30 one of the first and second sensor electrodes (120, 121) contains platinum.

7. A flow sensor according to claim 6, **characterized in that** the fluid contact surface of at least one of the first and second sensor electrodes (120, 121) is at least partly covered with platinum black.
- 5 8. An ultra-filtration measuring unit (500) for regulating at least one dialysis flow (Q' , Q''), **characterized in that** it comprises at least one flow sensor (100a, 100b) according to any one of the preceding claims.
- 10 9. An ultra-filtration measuring unit (500) according to claim 8, **characterized in that** it comprises a measurement cell (510), wherein first and second flow sensors (100a, 100b) are arranged with their conduit sections in parallel with each other such that a common magnetic field may magnetize flowing fluid in both the first flow sensor (100a) and the second flow sensor (100b).
- 15 10. A method for measuring a flow rate component (Q) of a fluid, which contains electrically charged elements, along a selected direction, involving:
- 20 magnetizing the fluid by means of a magnetic field (B) with a periodically alternating polarity having a magnetic axis which is oriented substantially perpendicular to the selected flow direction; and
- registering a voltage (U) across the flowing fluid along a line being substantially perpendicular both to the selected flow direction and the magnetic axis, **characterized by:**
- 25 feeding at least one control current (I_{ctrl-0} ; I_{ctrl-1}) to an electric sensor arrangement for registering the voltage (U), the at least one control current (I_{ctrl-0} ; I_{ctrl-1}) having such sign and magnitude that a direct-current voltage level at the electric sensor arrangement is controlled towards a predetermined
- 30 voltage (DC_{set}) relative a reference potential.

11. A method according to claim 10, **characterized by** the steps of:
- comparing the registered voltage (U) with the predetermined voltage (DC_{set}) to produce a variance there between;
 - 5 extracting a differential direct-current voltage component (ΔU_{LF}) from the variance;
 - producing a control current (I_{ctrl-0} ; I_{ctrl-1}) in response to the differential direct-current voltage component (ΔU_{LF}); and
 - 10 feeding the control current (I_{ctrl-0} ; I_{ctrl-1}) to the electric sensor arrangement.
12. A method according to claim 11, **characterized by** the production of the control current (I_{ctrl-0} ; I_{ctrl-1}) involving:
- receiving an adjustment signal (DC_{adj}) reflecting the differential direct-current voltage component (ΔU_{LF}) of the
 - 15 variance; and
 - generating the control current (I_{ctrl-0} ; I_{ctrl-1}) based on the adjustment signal (DC_{adj}).
13. A method according to any one of the claims 10 - 12, **characterized by** the magnetic field (B) having a base frequency different from a multiple of a standardized electricity
- 20 supply network frequency.
14. A method according to any one of the claims 10 - 13, **characterized by** the fluid containing glucose.

2/3

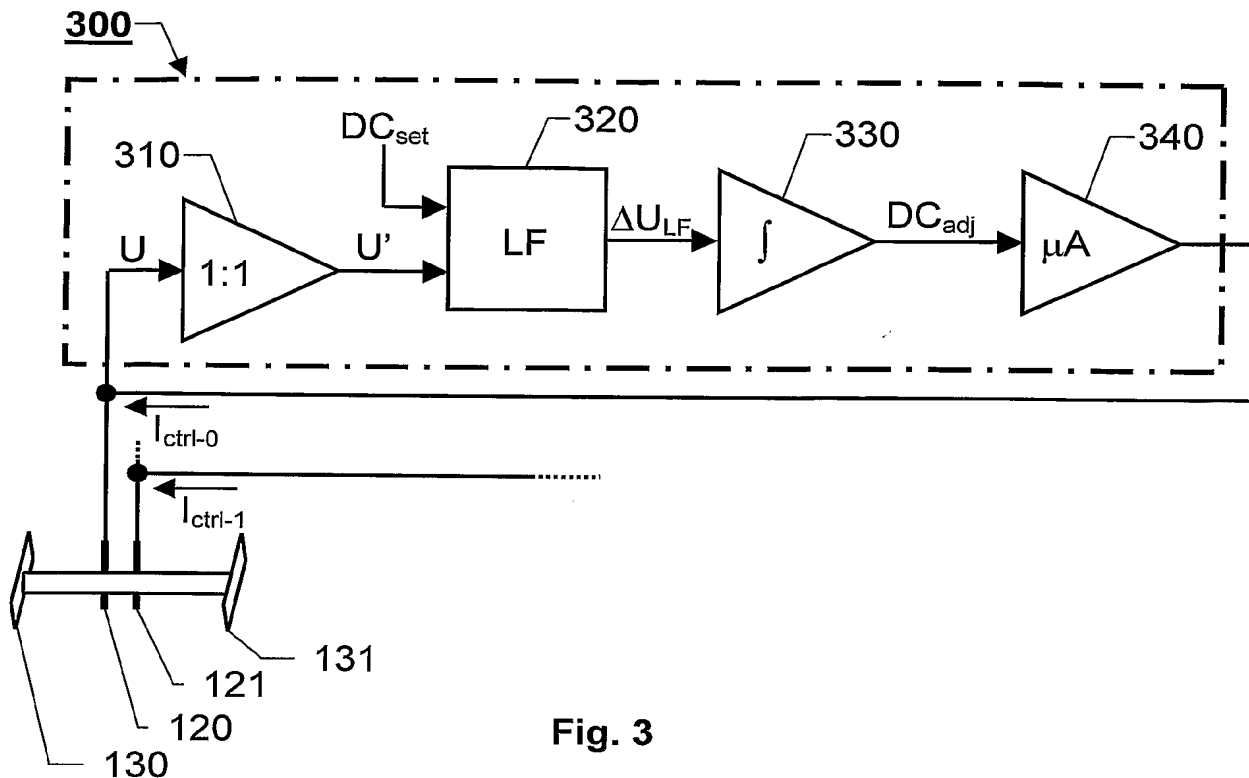


Fig. 3

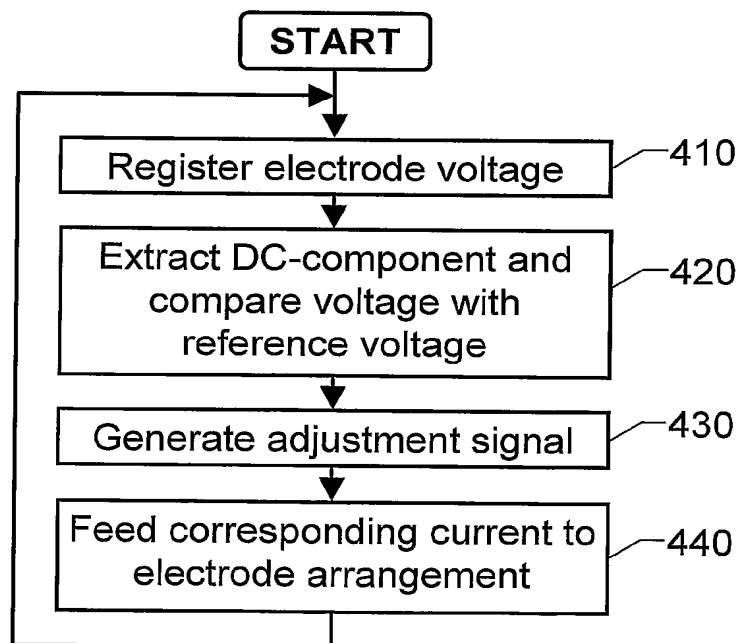


Fig. 4

3/3

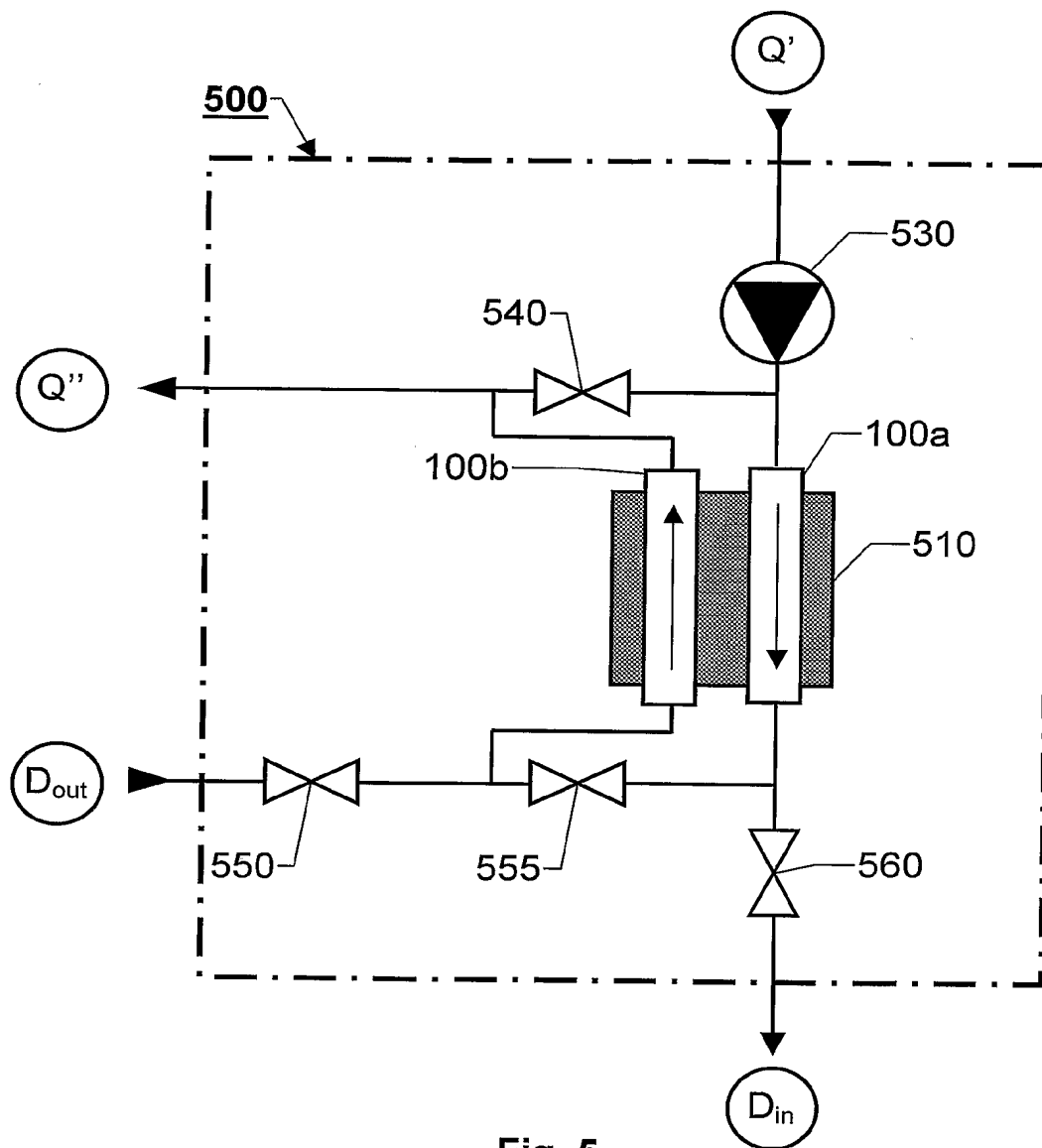


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 2004/000097

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01F 1/58, G01F 1/60
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENTS ABSTRACTS OF JAPAN vol. 010, no. 106(P-449), 22 April 1986 (1986-04-22) & JP 60237321 A (YOKOWAWA HOKUSHIN DENKI KK), 26 November 1985 (1985-11-26) abstract --	1-14
A	US 2003005777 A (BUDMIGER), 9 January 2003 (09.01.2003) --	1-14
A	US 2002145417 A1 (BROCKHAUS), 10 October 2002 (10.10.2002), page 3, line 21 - page 4, line 5 --	1-14

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 April 2004

Date of mailing of the international search report

26 -04- 2004

Name and mailing address of the ISA/

Swedish Patent Office

Box 5055, S-102 42 STOCKHOLM

Facsimile No. +46 8 666 02 86

Authorized officer

Henrik Eriksson /itw

Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 2004/000097

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6431011 B1 (FELLER), 13 August 2002 (13.08.2002), abstract -- -----	1-14

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 2004/000097

US 2003005777 A 09/01/2003

US	D472281 S	25/03/2003
EP	1273891 A	08/01/2003
EP	1273892 A	08/01/2003
WO	03004977 A	16/01/2003

US 2002145417 A1 10/10/2002

DE	10118003 A	24/10/2002
EP	1249687 A	16/10/2002
JP	2002328052 A	15/11/2002

US 6431011 B1 13/08/2002

US	2002050175 A	02/05/2002
US	6463807 B	15/10/2002
US	6571642 B	03/06/2003